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Broughton et al.

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(54) **FUEL SYSTEM FOR INTERNAL COMBUSTION ENGINE AND MARINE OUTBOARD ENGINE**

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F02M 25/08 (2006.01)
F02M 37/00 (2006.01)
F02B 61/04 (2006.01)

(52) **U.S. Cl.**
CPC ***F02M 25/0872*** (2013.01); ***F02M 25/089*** (2013.01); ***F02M 25/0836*** (2013.01); *F02B 61/045* (2013.01); *F02M 37/0052* (2013.01)

(58) **Field of Classification Search**
CPC F02M 25/08; F02M 25/0836; F02M 25/0872; F02M 25/086; F02M 25/089
USPC 123/516–518
See application file for complete search history.

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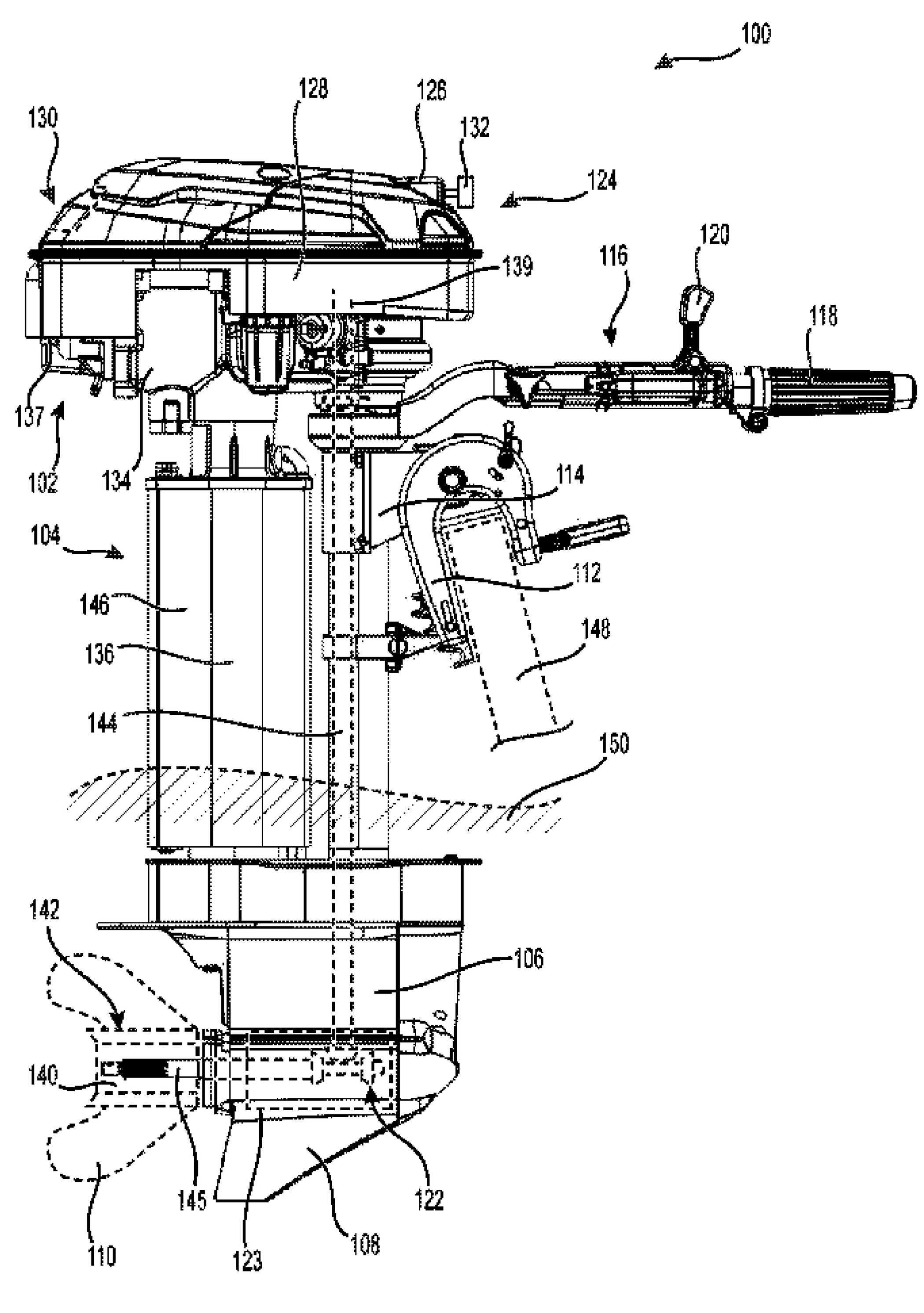
(57) **ABSTRACT**

A fuel system for an engine is provided. A fuel injector of the engine has an injector inlet and an injector outlet. The fuel system includes a fuel vapor separator, a fuel supply conduit, an injector conduit, a fuel return conduit, and a vapor return conduit. A first end of each of the fuel supply, injector and vapor return conduits is fluidly connected to the fuel vapor separator. A first end of the fuel return conduit is fluidly connectable to a fuel tank. A second end of the fuel supply conduit is fluidly connectable to the fuel tank. A second end of the injector conduit is fluidly connectable to the injector inlet. A second end of the fuel return conduit is fluidly connectable to the injector outlet. A second end of the vapor return conduit is fluidly connectable to the fuel tank. A marine outboard engine is also provided.

16 Claims, 7 Drawing Sheets



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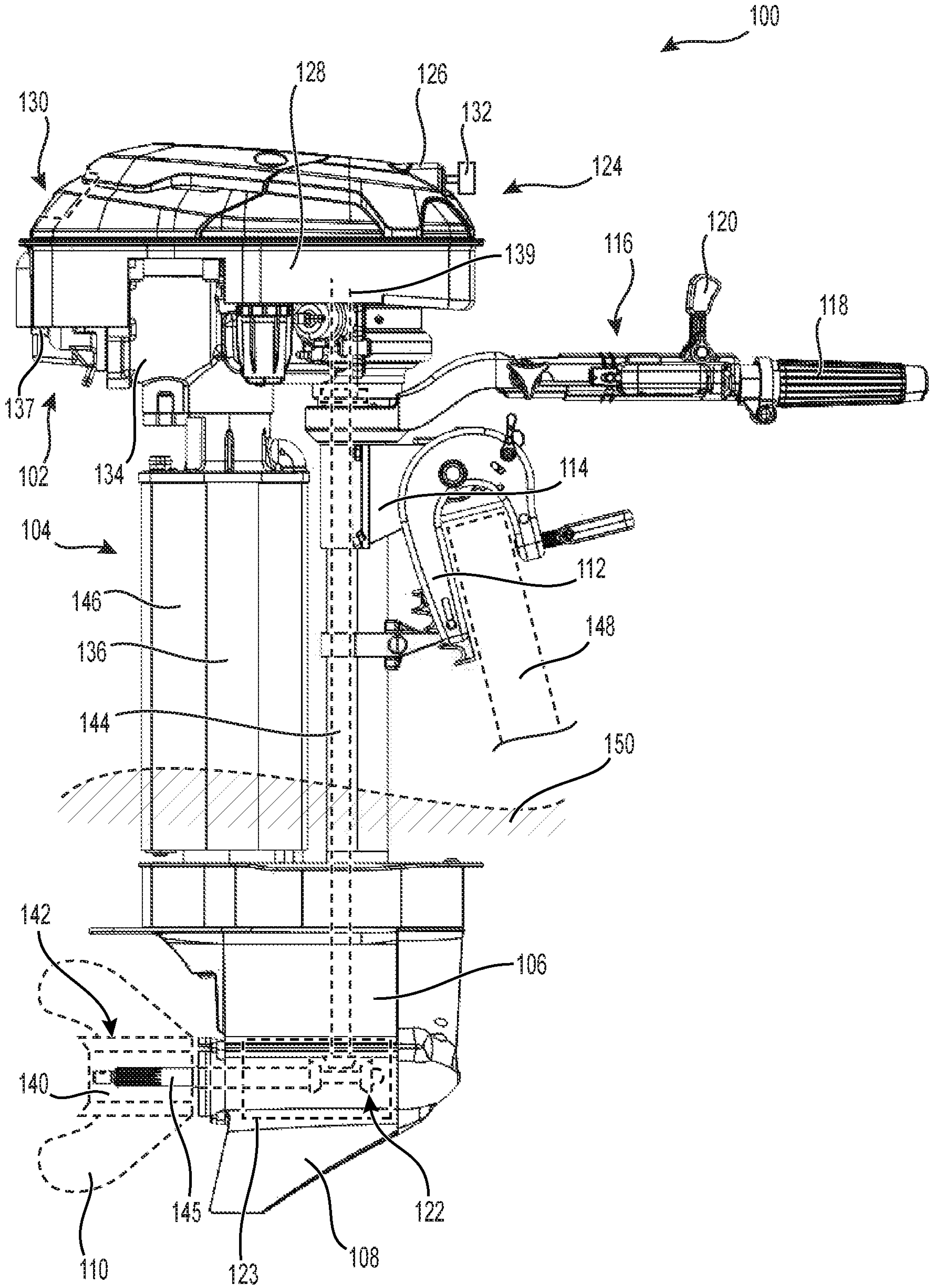
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FIG. 1

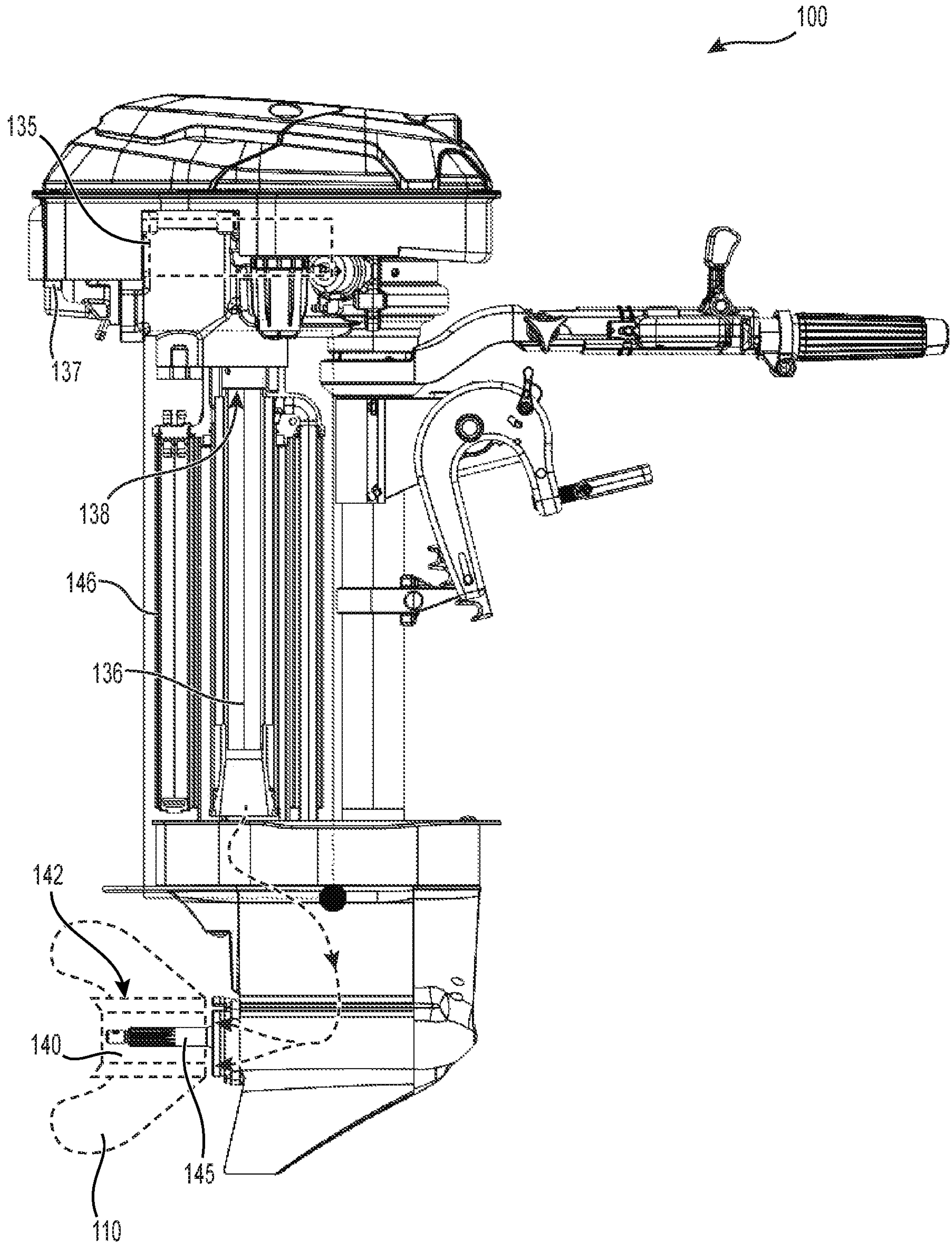

FIG. 2

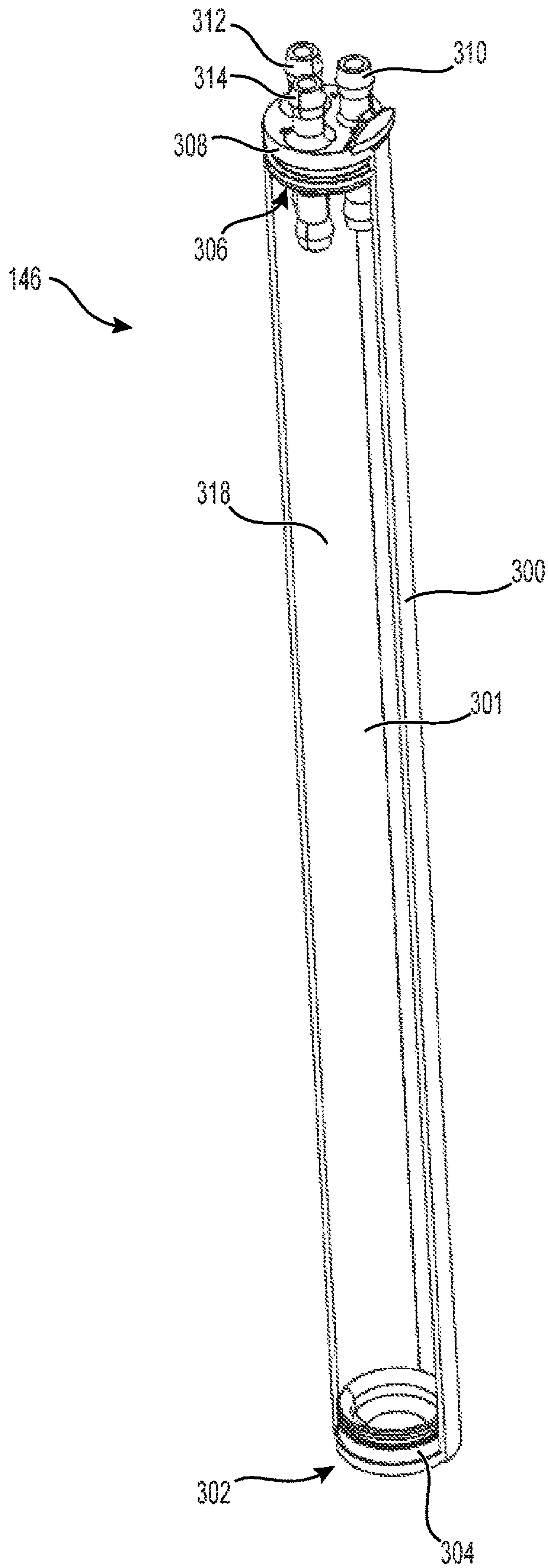

FIG. 3

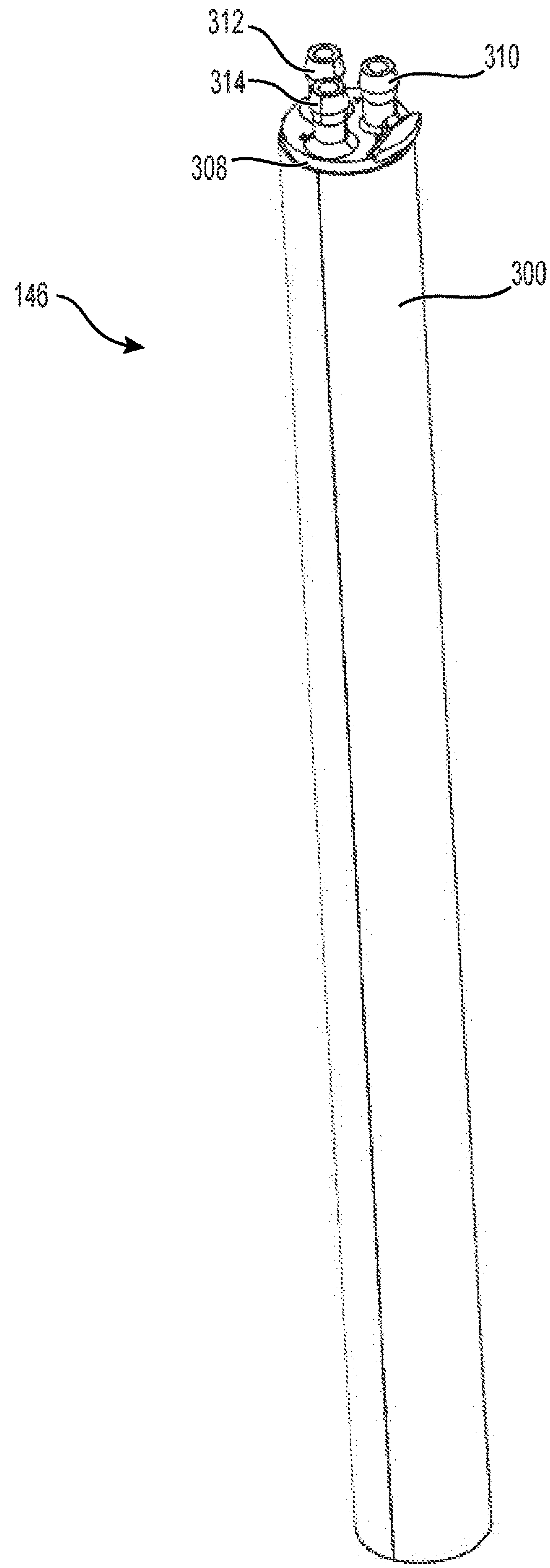

FIG. 4

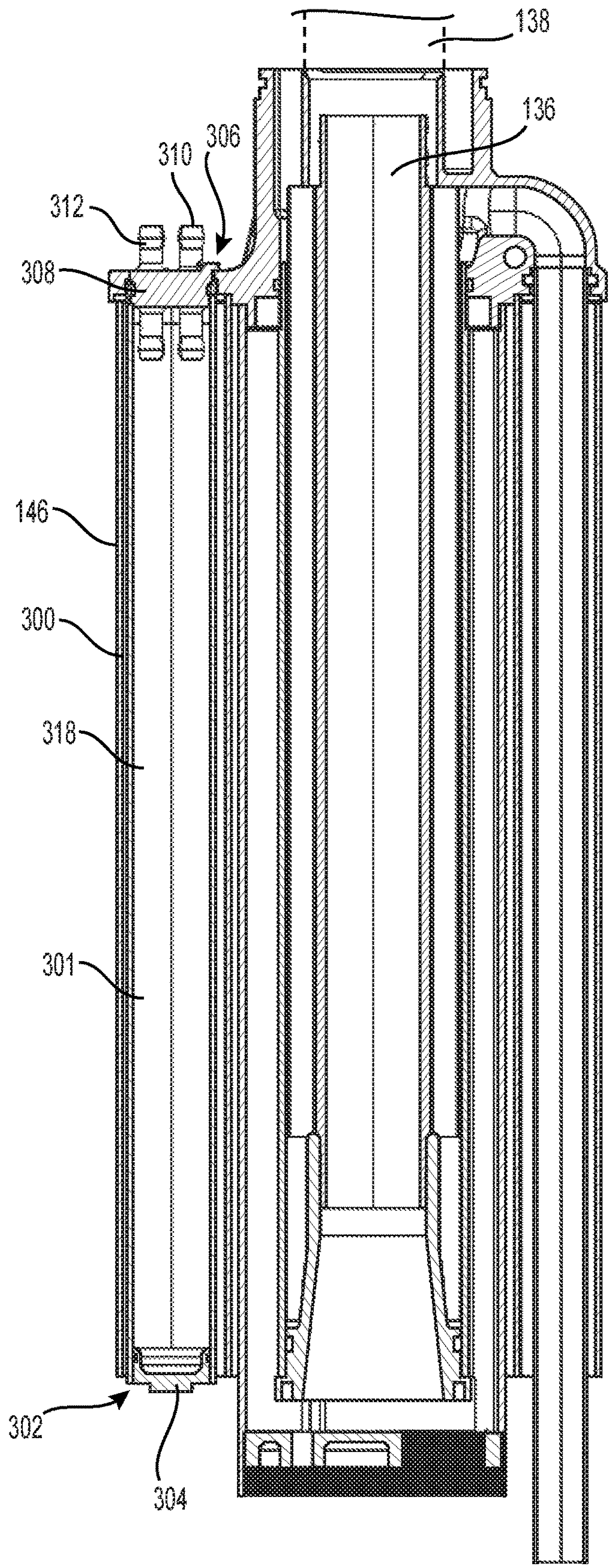

FIG. 5

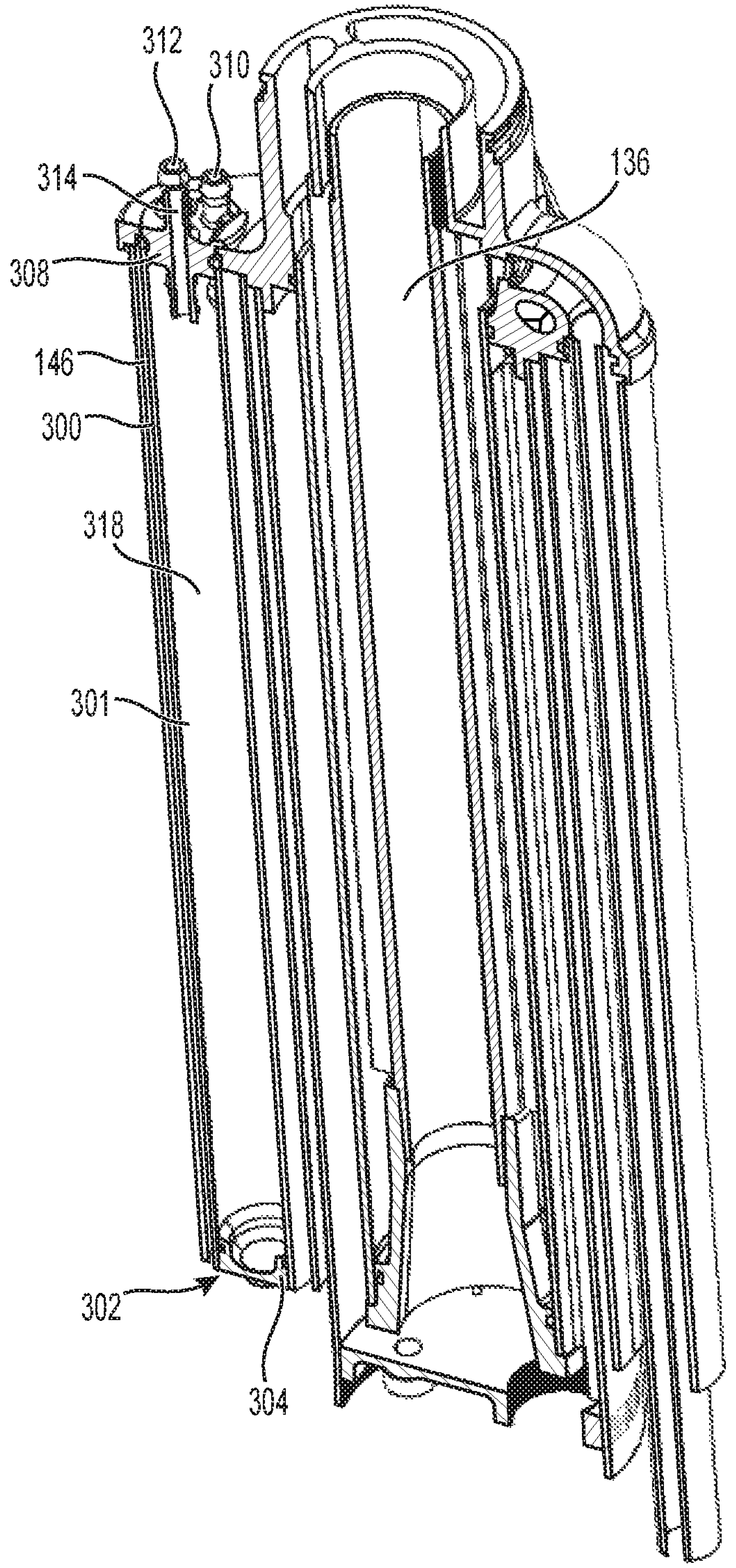

FIG. 6

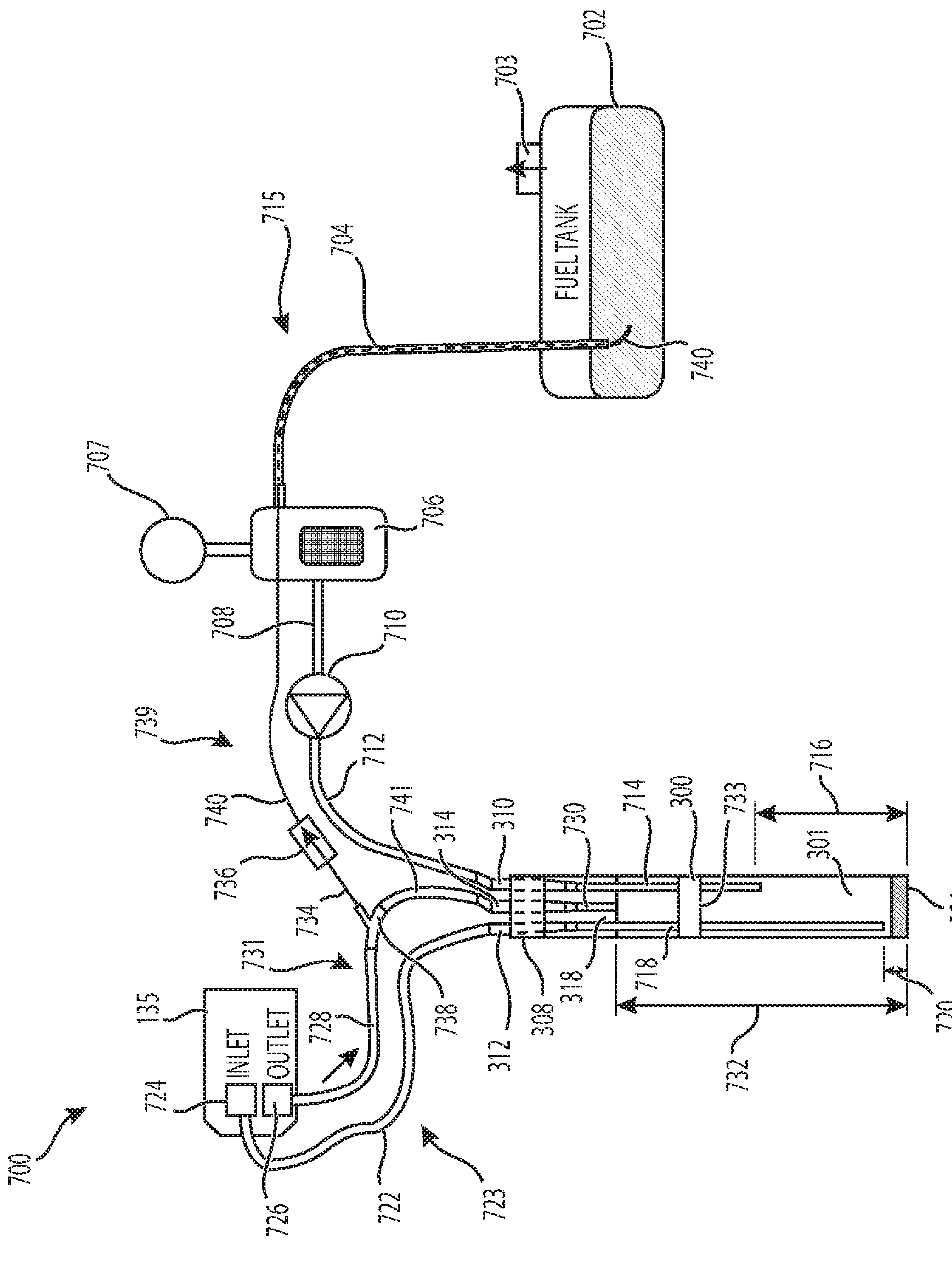

FIG. 7

FUEL SYSTEM FOR INTERNAL COMBUSTION ENGINE AND MARINE OUTBOARD ENGINE

CROSS-REFERENCE

The present application claims priority to U.S. Provisional patent Application No. 62/579,784, entitled "FUEL SYSTEM FOR INTERNAL COMBUSTION ENGINE AND MARINE OUTBOARD ENGINE", filed Oct. 31, 2017, the entirety of which is incorporated herein by reference.

TECHNICAL FIELD

The present technology relates to fuel systems for internal combustion engines and more particularly to fuel systems for marine outboard engines.

BACKGROUND

A typical gasoline-powered marine outboard engine has an internal combustion engine for propelling the marine outboard engine, the internal combustion engine having at least one cylinder and at least one corresponding fuel injector that injects gasoline into the at least one cylinder for powering the engine.

Gasoline is typically delivered to the fuel injector(s) via a fuel system that has two fuel pumps and a fuel vapor separator. A first fuel pump of the two fuel pumps draws fuel from a fuel tank and supplies it to the fuel vapor separator when fuel in the fuel vapor separator drops below a certain threshold detected by a sensor. Typically, the sensor is a float sensor, but alternate types of sensor, such as electronic level sensors, are possible. The first fuel pump is typically a low cost, low-pressure, low precision, fuel pump. One example of such a fuel pump is a conventionally known pulse pump.

A second fuel pump of the two fuel pumps delivers fuel from the vapor separator to the fuel injector(s) of the internal combustion engine. The second fuel pump is typically a high-pressure pump that has a more complicated construction than the first fuel pump, which provides a higher fuel delivery precision than the first fuel pump. The second fuel pump is therefore typically more expensive than the first fuel pump. The higher-precision fuel delivery of the second fuel pump is used to maintain proper operation of the fuel injector(s). More particularly, the higher-precision fuel delivery of the second fuel pump is used to maintain the flow rate and pressure of the fuel supply at the fuel injector(s) in a range of flow rates and pressures that is required by the fuel injector(s).

Not all the fuel pumped to the injector(s) is consumed by the internal combustion engine. A portion of the fuel pumped to the injector(s) is allowed to flow past and thereby cool the fuel injector(s). In some systems, fuel is returned to the fuel vapor separator from the injector(s) and this returned fuel is typically warmer than fuel delivered to the fuel vapor separator from the fuel tank. Such returned fuel is therefore more volatile than cooler fuel, and may be foamy. Fuel in the fuel vapor separator, and especially the warmer fuel in the fuel vapor separator, produces fuel vapor. Fuel vapor is typically vented from a top part of the fuel vapor separator to the internal combustion engine's air intake, where it is consumed during the internal combustion engine's operation.

One example of a conventional fuel system for a marine outboard engine is taught by U.S. Pat. No. 6,257,208.

Another example of a conventional fuel system for a marine outboard engine is taught by U.S. Pat. No. 4,722,708.

Conventional fuel systems are suitable for their intended purposes. However, in one aspect, conventional fuel systems are relatively expensive because they have two fuel pumps, one of which is typically a high precision fuel pump and therefore expensive.

Therefore, there is a desire to reduce marine outboard engine cost.

SUMMARY

It is an object of the present technology to ameliorate at least some of the inconveniences present in the prior art.

For the purposes of this document, the term "conduit" refers to a notional fluid connection and is defined by at least one physical line and/or other components that define at least one fluid conduit (such as a fuel pump, a fuel filter, a valve, and the like). For example, in some embodiments, a fuel "conduit" that connects points A and B is defined by a single (physical) fuel line connecting the points A and B. As another example, in some embodiments, the fuel "conduit" is defined by two (physical) fuel lines interconnected in series or parallel, and connecting the points A and B. In other examples, the fuel "conduit" could also be defined by more than two (physical) fuel lines interconnected in series, parallel, or a combination of series and parallel, and connecting the points A and B.

In turn, for the purposes of this document, the term "line" refers to a physical line for conveying a fluid, such as gasoline or fuel vapor. One example of a fuel line is a fuel hose. Another example of a fuel line is a plastic tube.

For the purposes of this document, the term "gas" refers to fuel vapor alone, air alone, or a combination of fuel vapor and air. It is to be understood that the gas can also include water vapor and other constituents.

For the purposes of this document, the term "fluid" refers to a gas alone, a liquid (such as gasoline) alone, or a combination of one or more gases and one or more liquids.

According to one aspect of the present technology, there is provided a fuel system for an internal combustion engine, the internal combustion engine being for use with a fuel tank and having a fuel injector, the fuel injector having an injector inlet for receiving a fuel supply and an injector outlet in fluid communication with the injector inlet for recirculating at least some of the fuel supply received by the injector inlet when the internal combustion engine operates.

The fuel system includes a fuel vapor separator, a fuel supply conduit, an injector conduit, a fuel return conduit, and a vapor return conduit. A first end of the fuel supply conduit is fluidly connected to the fuel vapor separator. A second end of the fuel supply conduit is fluidly connectable to the fuel tank for supplying fuel from the fuel tank to the fuel vapor separator. A first end of the injector conduit is fluidly connected to the fuel vapor separator. A second end of the injector conduit is fluidly connectable to the injector inlet for supplying fuel from the fuel vapor separator to the injector inlet. A first end of the fuel return conduit is fluidly connectable to the fuel tank. A second end of the fuel return conduit is fluidly connectable to the injector outlet for returning fuel from the injector outlet to the fuel tank. A first end of the vapor return conduit is fluidly connected to the fuel vapor separator. A second end of the vapor return conduit is fluidly connectable to the fuel tank.

In some embodiments, the fuel system further includes a fuel pump fluidly connected to the fuel supply conduit. The fuel pump is operable to supply fuel from the fuel tank to the fuel vapor separator via the fuel supply conduit when the second end of the fuel supply conduit is fluidly connected to the fuel tank.

In some embodiments, the fuel pump is the only fuel pump of the fuel system.

In some embodiments, the fuel pump is fluidly within the fuel supply conduit.

In some embodiments, the fuel pump is a pulse pump.

In some embodiments, the fuel system includes the fuel tank, the second end of the fuel supply conduit is fluidly connected to the fuel tank, and the fuel tank has a pressure relief valve operable to release fuel vapor pressure in the fuel tank to ambient air when the fuel vapor pressure reaches a first predetermined pressure threshold.

In some embodiments, the fuel system includes a check valve positioned in the vapor return conduit. The check valve prevents fluid flow through the check valve in a fluid direction from the fuel tank toward the fuel vapor separator. The check valve prevents fluid flow through the check valve in a fluid direction from the fuel vapor separator toward the fuel tank when fluid pressure in the vapor return conduit fluidly upstream of the check valve is below a second predetermined pressure threshold. In another aspect, the check valve permits fluid flow through the check valve in the fluid direction from the fuel vapor separator toward the fuel tank when fluid pressure in the vapor return conduit fluidly upstream of the check valve is above the second predetermined pressure threshold.

In some embodiments, the vapor return conduit includes a vapor return line fluidly upstream of the check valve, a terminal opening in one end of the vapor return line defines the first end of the vapor return conduit, and the terminal opening in the one end of the vapor return line is located in the fuel vapor separator.

In some embodiments, the vapor return conduit and the fuel return conduit fluidly overlap at least in part.

In some embodiments, the fuel return conduit includes a fuel return line and the vapor return conduit includes a vapor return line physically connected to the fuel return line.

In some embodiments, the vapor return conduit includes a vapor return line, the fuel supply conduit includes a fuel line, and the vapor return line is located within the fuel line.

In some embodiments, the fuel system includes a fuel filter fluidly positioned in the fuel supply conduit, the vapor return conduit includes a vapor return line, the fuel supply conduit includes a fuel line, and the vapor return line is within the fuel line at least between the fuel filter and the fuel tank.

In some embodiments, the fuel vapor separator includes an elongate body that defines a pressurizable fuel chamber therein, and the fuel chamber is structured to have a column of gas in a top part of the fuel chamber when the fuel system operates.

In some embodiments, a terminal opening at the first end of the fuel supply conduit is within the fuel chamber and is located at a first height measured from a bottom surface of the fuel chamber, a terminal opening at the first end of the injector conduit is within the fuel chamber and is located at a second height measured from the bottom surface of the fuel chamber, a terminal opening at the first end of the vapor return conduit is within the fuel chamber and is located at a third height measured from the bottom surface of the fuel chamber, the second height is smaller than the first height, and the third height is greater than the first height.

According to another aspect of the present technology, there is provided a marine outboard engine. The marine outboard engine includes an internal combustion engine having a crankshaft, a fuel injector, the fuel injector having an injector inlet for receiving a fuel supply and an injector outlet in fluid communication with the injector inlet for recirculating at least some of the fuel supply received by the injector inlet when the internal combustion engine operates.

The marine outboard engine also includes a driveshaft having a first end connected to the crankshaft, and a second end opposite the first end; a transmission connected to the second end of the driveshaft to be driven by the driveshaft; an output shaft having a first end connected to the transmission to be selectively driven by the transmission, and a second end opposite the first end; a rotor connected to the second end of the output shaft to driven by the output shaft for propelling the marine outboard engine; and a fuel vapor separator.

In another aspect, the marine outboard engine also includes a fuel supply conduit, an injector conduit, a fuel return conduit, and a vapor return conduit. A first end of the fuel supply conduit is fluidly connected to the fuel vapor separator. A second end of the fuel supply conduit is fluidly connectable to the fuel tank for supplying fuel from the fuel tank to the fuel vapor separator. A first end of the injector conduit is fluidly connected to the fuel vapor separator.

Also, a second end of the injector conduit is fluidly connected to the injector inlet for supplying fuel from the fuel vapor separator to the injector inlet. A first end of the fuel return conduit is fluidly connectable to the fuel tank. A second end of the fuel return conduit is fluidly connected to the injector outlet for returning fuel from the injector outlet to the fuel tank. A first end of the vapor return conduit is fluidly connected to the fuel vapor separator. A second end of the vapor return conduit is fluidly connectable to the fuel tank.

In some embodiments, the marine outboard engine further includes a fuel pump fluidly connected to the fuel supply conduit to be operable to supply fuel from the fuel tank to the fuel vapor separator via the fuel supply conduit when the second end of the fuel supply conduit is fluidly connected to the fuel tank.

In some embodiments, the fuel pump is the only fuel pump of the marine outboard engine.

In some embodiments, the fuel pump is fluidly within the fuel supply conduit.

In some embodiments, the fuel pump is a pulse pump.

In some embodiments, the marine outboard engine includes the fuel tank, the second end of the fuel supply conduit is fluidly connected to the fuel tank, and the fuel tank has a pressure relief valve operable to release fuel vapor pressure in the fuel tank to ambient air when the fuel vapor pressure reaches a first predetermined pressure threshold.

In some embodiments, the marine outboard engine includes a check valve positioned in the vapor return conduit. The check valve prevents fluid flow through the check valve in a fluid direction from the fuel tank toward the fuel vapor separator. The check valve also prevents fluid flow through the check valve in a fluid direction from the fuel vapor separator toward the fuel tank when fluid pressure in the vapor return conduit fluidly upstream of the check valve is below a second predetermined pressure threshold. The check valve also permits fluid flow through the check valve in the fluid direction from the fuel vapor separator toward the fuel tank when fluid pressure in the vapor return conduit fluidly upstream of the check valve is above the second predetermined pressure threshold.

In some embodiments, the vapor return conduit includes a vapor return line fluidly upstream of the check valve, a terminal opening in one end of the vapor return line defines the first end of the vapor return conduit, and the terminal opening in the one end of the vapor return line is located in the fuel vapor separator.

In some embodiments, the vapor return conduit and the fuel return conduit fluidly overlap at least in part.

In some embodiments, the fuel return conduit includes a fuel return line and the vapor return conduit includes a vapor return line physically connected to the fuel return line.

In some embodiments, the vapor return conduit includes a vapor return line, the fuel supply conduit includes a fuel line, and the vapor return line is located within the fuel line.

In some embodiments, the marine outboard engine includes a fuel filter fluidly positioned in the fuel supply conduit, the vapor return conduit includes a vapor return line, the fuel supply conduit includes a fuel line, and the vapor return line is within the fuel line at least between the fuel filter and the fuel tank.

In some embodiments, the fuel vapor separator includes an elongate body that defines a pressurizable fuel chamber therein, and the fuel chamber is structured to have a column of gas in a top part of the fuel chamber when the internal combustion engine operates.

In some embodiments, a terminal opening at the first end of the fuel supply conduit is within the fuel chamber and is located at a first height measured from a bottom surface of the fuel chamber; a terminal opening at the first end of the injector conduit is within the fuel chamber and is located at a second height measured from the bottom surface of the fuel chamber; a terminal opening at the first end of the vapor return conduit is within the fuel chamber and is located at a third height measured from the bottom surface of the fuel chamber; the second height is smaller than the first height; and the third height is greater than the first height.

In some embodiments, the elongate body extends at least in part parallel to the driveshaft.

In some embodiments, the fuel vapor separator is positioned relative to the internal combustion engine such that when the marine outboard engine is attached to a transom of a watercraft in a body of water and is in an in-use position, at least a part of the fuel vapor separator is submerged in the body of water.

In some embodiments, the elongate body is located below the crankshaft and above the output shaft.

The foregoing examples are non-limiting.

For purposes of this application, terms related to spatial orientation such as forward, rearward, upward, downward, left, and right, should be understood in a frame of reference where the propeller position corresponds to a rear of the marine outboard engine. Terms related to spatial orientation when describing or referring to components or sub-assemblies of the engine separately from the engine should be understood as they would be understood when these components or sub-assemblies are mounted to the engine, unless specified otherwise in this application.

Implementations of the present technology each have at least one of the above-mentioned object and/or aspects, but do not necessarily have all of them. It should be understood that some aspects of the present technology that have resulted from attempting to attain the above-mentioned object may not satisfy this object and/or may satisfy other objects not specifically recited herein.

Additional and/or alternative features, aspects and advantages of implementations of the present technology will become apparent from the following description, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the present technology, as well as other aspects and further features thereof, reference is made to the following description which is to be used in conjunction with the accompanying drawings, where:

FIG. **1** is a right side elevation view of a marine outboard engine, with fuel lines omitted to maintain clarity;

FIG. **2** is a right side elevation, partial sectional view of the marine outboard engine of FIG. **1**, taken along a central longitudinal vertical plane passing through the marine outboard engine;

FIG. **3** is a perspective, partial sectional view of a fuel vapor separator of the marine outboard engine of FIG. **1**;

FIG. **4** is a perspective view of the fuel vapor separator of the marine outboard engine of FIG. **1**;

FIG. **5** is a right side elevation, cross-sectional view of a midsection of the marine outboard engine of FIG. **1**, taken along a central longitudinal vertical plane passing through the midsection of the marine outboard engine;

FIG. **6** is a perspective, partial sectional view of the midsection of the marine outboard engine of FIG. **1**; and

FIG. **7** is a schematic showing a fuel system of the marine outboard engine of FIG. **1**, including the fuel lines omitted from FIG. **1**.

DETAILED DESCRIPTION

The present technology is described with reference to its use in a marine outboard engine **100** that is used to propel a watercraft. It is contemplated that the present technology could have other uses, including a use in other small engine applications.

To maintain clarity of this description, fuel lines of the marine outboard engine **100** have been omitted from FIGS. **1** to **6**. The fuel lines and other components of a fuel system **700** of the marine outboard engine **100** are instead shown schematically in FIG. **7** and are described in more detail later in this document. In the embodiment described in FIGS. **1** to **7**, all of the fuel lines are conventionally known marine-grade fuel hoses. It is contemplated that the fuel lines could be any other suitable fuel lines.

Now referring to FIG. **1**, the marine outboard engine **100** includes an engine assembly **102** for powering the marine outboard engine **100**, a mid-section **104**, a gearcase **106**, a skeg portion **108** and a propeller **110** (shown in phantom lines in FIG. **1**).

A stern bracket **112** and a swivel bracket **114** are used to mount the marine outboard engine **100** to a watercraft. The stern bracket **112** is attachable to a watercraft and can take various forms, the details of which are conventionally known. The swivel bracket **114** pivotally connects to the stern bracket **112** to allow for changes in the tilt/trim of the marine outboard engine **100**, The mid-section **104** pivotally connects to the swivel bracket **114** to allow for steering of the marine outboard engine **100**. It is contemplated that any other mechanism could be used for mounting the marine outboard engine **100** onto a watercraft.

In the implementation shown in FIG. **1**, a tiller **116** is connected to the swivel bracket **114** and provides a lever used for manually steering of the marine outboard engine **100**. The tiller **116** is rotationally fastened to the swivel bracket **114** such that it can be raised for ease of handling and transportation. The tiller **116** includes a handle **118** in the form of a twist grip used as throttle control as in most conventional small marine outboard engines.

The tiller **116** also includes a shift lever **120** for selecting a forward, neutral or reverse gear of a transmission **122** (housed in a gearcase chamber **123** defined in the gearcase **106**, as shown schematically in FIG. **1**) of the marine outboard engine **100**. It is contemplated that the tiller **116** could be any other tiller. It is also contemplated that the tiller **116** could be omitted and that the marine outboard engine **100** could be steered using a steering wheel connected to a cable, hydraulic, electric or a combination steering system. It is contemplated that the throttle of the marine outboard engine **100** and the transmission **122** could be controlled by one or more levers disposed near the steering wheel.

The marine outboard engine **100** has a cowling **124**. The cowling **124** surrounds and protects the engine assembly **102**. In the present embodiment, the engine assembly **102** is covered in part by the cowling **124**. The cowling **124** includes an upper motor cover assembly **126** and a lower motor cover **128**.

The upper motor cover assembly **126** and the lower motor cover **128** are made of molded plastic, but could also be made of metal, composite or the like. The lower motor cover **128** and/or other components of the cowling **124** can be formed as a single piece or as several pieces. For example, the lower motor cover **128** can be formed as two lateral pieces mating along a vertical joint. The lower motor cover **128** is also made, in part, of molded plastic, but could also be made of metal, composites or the like. One suitable composite is a sheet molding compound (SMC) which is typically a fiberglass reinforced sheet molded to shape.

A seal (not shown) is disposed between the upper motor cover assembly **126** and the lower motor cover **128** to form a watertight connection. One or more locking mechanisms (not shown) are provided on at least one of the sides and/or at the front and/or back of the cowling **124** to lock the upper motor cover assembly **126** onto the lower motor cover **128**.

The upper motor cover assembly **126** includes an air intake portion **130** (shown schematically in FIG. **1**) formed as a recessed portion on the rear of the cowling **124**. The air intake portion **130** is configured to allow the entry of air but prevent the entry of water **150** into the interior of the cowling **124** and then into the engine assembly **102**. Such a configuration can include a tortuous path for example.

It is contemplated that the air intake portion **130** could be defined elsewhere on the cowling **124**. The upper motor cover assembly **126** also defines an aperture (not shown) against which a handle **132** of a manual start assembly (not shown) is received. In the present embodiment, the manual start assembly is a rope-pull start assembly and will not be described herein in detail. It is contemplated that the marine outboard engine **100** could have an electric start assembly (not shown) in addition to or in substitution of the manual start assembly.

The engine assembly **102** includes an internal combustion engine **134**. In the present embodiment, the internal combustion engine **134** is a two-stroke, gasoline-powered, direct injected internal combustion engine. It is contemplated that the internal combustion engine **134** could be a four-stroke direct injected internal combustion engine. It is contemplated that the internal combustion engine **134** could use a fuel other than gasoline, such as diesel.

A driveshaft **144** (shown schematically in FIG. **1**) of the marine outboard engine **100** is connected to a crankshaft **139** of the internal combustion engine **134**. The driveshaft **144** extends downward from the internal combustion engine **134** through the mid-section **104** and into the gearcase **106**. The mid-section **104** extends downward from the engine assembly **102** to the gearcase **106** and connects the engine assembly **102** to the gearcase **106**.

The propeller **110** is mounted onto a output shaft **145** that is rotationally supported by the gearcase **106** and extends rearward out of the gearcase chamber **123**. The transmission **122** selectively couples the driveshaft **144** to the output shaft **145** for transferring power from the internal combustion engine **134** to the propeller **110** to propel the marine outboard engine **100**. In the present embodiment, the transmission **122** is a mechanical outboard transmission that is operable by the shift lever **120**. It is contemplated that the transmission **122** could be operated by a different mechanism (in which case the marine outboard engine **100** would have the different mechanism instead of the shift lever **120**). It is contemplated that the marine outboard engine **100** could have any other transmission.

Reference is now made to FIG. **2**. When the internal combustion engine **134** operates, it produces exhaust fumes. To this end, an exhaust conduit **136** connects an exhaust port **138** of the internal combustion engine **134** to an exhaust outlet **140** defined in a propeller hub **142** (schematically shown in FIGS. **1** and **2**) of the propeller **110**.

In the present embodiment, and as schematically shown in FIG. **2**, the exhaust conduit **136** extends from the exhaust port **138**, downward through the mid-section **104**, along the output shaft **145**, through the propeller hub **142**, and terminates at the exhaust outlet **140**. It is contemplated that the exhaust conduit **136** could be routed differently. It is also contemplated that the exhaust outlet **140** could be defined elsewhere in the marine outboard engine **100**.

In the present embodiment, the internal combustion engine **134** has a single cylinder **135** (shown schematically in FIG. **2**) and a single conventionally known fuel injector **137** that directly injects fuel into the single cylinder **135** of the internal combustion engine **134**. It is contemplated that the internal combustion engine **134** could have more than one cylinder **135** and/or more than one fuel injector **137**. It is further contemplated that the internal combustion engine **134** could be other than a direct injected engine.

The marine outboard engine **100** includes a fuel vapor separator **146** for, inter alia, deaerating and delivering fuel to the fuel injector **137**. Referring now to FIGS. **3** to **6**, in the present embodiment, the fuel vapor separator **146** has a metallic wall **300** that defines an elongate body. In the present embodiment, the elongate body is an elongate cylinder **301** having a circular cross-section. It is contemplated that the elongate body could have other shapes.

As best shown in FIGS. **5** and **6**, the elongate cylinder **301** is mounted alongside the exhaust conduit **136** in the mid-section **104** of the marine outboard engine **100**, parallel to the exhaust conduit **136**. It is contemplated that the elongate cylinder **301** need not be parallel to the exhaust conduit **136**. In another aspect, the elongate cylinder **301** is located below the crankshaft **139** of the internal combustion engine **134** and above the output shaft **145**.

As best shown in FIG. **3**, the elongate cylinder **301** has an aperture **302** defined its bottom end. The aperture **302** is closed by a plastic plug **304** that is pressed into the aperture **302**. A conventionally known seal (not shown) is disposed radially between the plug **304** and a part of the wall **300** that defines the aperture **302**. The seal thereby fluidly seals the bottom end of the fuel vapor separator **146**. It is contemplated that the bottom end of the elongate cylinder **301** could be fluidly sealed using any other suitable construction of the plug **304** and/or the wall **300**. For example, the wall **300** and the plug **304** could be provided with correspondingly threaded surfaces for retaining the plug **304** in the aperture **302**, or the plug **304** could be glued, welded or otherwise fixed in place. The wall **300** could also define the elongate cylinder **301** as a cylinder open at its top end and closed at its bottom end.

In another aspect, the elongate cylinder **301** of the fuel vapor separator **146** has another aperture **306** defined its top end. A circumferential groove is defined on an inner side of the wall **300** in the aperture **306**. A plastic plug **308** has a circumferential projection and is press fitted into the aperture **306** such that the circumferential projection is mateably received in the circumferential groove in the wall **300** and thereby fluidly seals the interface the wall **300** and the plastic plug **308**. It is contemplated that this interface could be fluidly sealed using any other suitable construction, such as those mentioned above. It is also contemplated that the plugs **304**, **308** and/or the wall **300** could be made of any other suitable material(s).

The wall **300** of the fuel vapor separator **146** and the plugs **304**, **308** define a fuel chamber **318** (inside the elongate body). The (top) plug **308** has three fluid connectors **310**, **312**, **314** defined therethrough. Each of the fluid connectors **310**, **312**, **314** fluidly connects to the fuel chamber **318**.

As schematically shown in FIG. **7**, fuel is supplied to the fuel chamber **318** from a fuel tank **702**. More particularly, in the present embodiment, a first fuel line **704** fluidly connects the fuel tank **702** to a fuel filter **706**. A second fuel line **708** fluidly connects the fuel filter **706** to a fuel pump **710**. A third fuel line **712** fluidly connects the fuel pump **710** to a top end of the fluid connector **310**. A fourth fuel line **714** is fluidly connected to a bottom end of the fluid connector **310** and extends downward into the fuel chamber **318** to a first height **716** measured from a bottom surface of the fuel chamber **318**.

While the internal combustion engine **134** operates, the fuel pump **710** supplies fuel from the fuel tank **702** to the fuel chamber **318** via the first fuel line **704**, the fuel filter **706**, the second fuel line **708**, the third fuel line **712**, the fluid connector **310** and the fourth fuel line **714**. In other words, the first fuel line **704**, the fuel filter **706**, the second fuel line **708**, the third fuel line **712**, the fluid connector **310** and the fourth fuel line **714** define a fuel supply conduit **715**. It is contemplated that the fuel supply conduit **715** could be defined by different elements, such as other and/or additional fuel lines.

In the present embodiment, the fuel tank **702** is a conventional marine outboard engine fuel tank that has a fuel vapor pressure relief valve **703** for relieving pressure of fuel vapor in the fuel tank **702**. The fuel vapor pressure relief valve **703** opens and thereby fluidly connects the fuel tank **702** to ambient air when pressure of fuel vapor in the fuel tank **702** exceeds 5 pounds-per-square-inch ("psi"). It is contemplated that a different fuel tank and/or a different vapor pressure relief valve **703** could be used.

In the present embodiment, the fuel filter **706** is a conventionally known marine outboard engine fuel filter that has a primer bulb for priming the fuel system **700** of the internal combustion engine **134** to prepare the internal combustion engine **134** for a cold start. It is contemplated that a different fuel filter could be used and/or that the primer bulb could be located elsewhere within the fuel system **700**.

In the present embodiment, the fuel pump **710** is a conventionally known pulse pump that is driven by crankcase pressure of the internal combustion engine **134** and generates fifteen psi of pressure. It is contemplated that the fuel pump **710** could be place elsewhere in the fuel system **700**. It is also contemplated that the fuel pump **710** could be any other suitable fuel pump and could be selected to provide any other suitable pumping pressure, depending on the particular embodiments of the other components of the fuel system of the marine outboard engine **100**. In one example, the fuel pump **710** could be an electric pump positioned within the chamber **318** of the vapor separator **146**.

Fuel supplied to the fuel chamber **318** deaerates in the fuel chamber **318**, and is supplied from a bottom of the fuel chamber **318** to an injector inlet **724** of the fuel injector **137**. To this end, a fifth fuel line **718** is fluidly connected to a bottom end of the fluid connector **312** and extends downward into the fuel chamber **318** to a second height **720** measured from the bottom surface of the fuel chamber **318**. A sixth fuel line **722** fluidly connects a top end of the fluid connector **312** to the injector inlet **724**.

In the present embodiment, the second height **720** is a lowest point in the fuel chamber **318**. This reduces risk of supplying the injector inlet **724** with fuel that contains air bubbles and/or vapor bubbles (which are more likely to be present fuel in an upper half of the fuel chamber **318** than in a lower half of the fuel chamber **318**) during normal operation. In some embodiments, the second height **720** could be higher than the lowest point in the fuel chamber **318**.

During operation of the internal combustion engine, the fuel pump **710** supplies fuel to the fuel chamber **318** and thereby pressurizes the fuel chamber **318**. Fuel from the fuel chamber **318** is, in turn, supplied from the fuel chamber **318** to the injector inlet **724** via the fifth fuel line **718**, the fuel connector **312** and the sixth fuel line **722**. In other words, the fifth fuel line **718**, the fuel connector **312** and the sixth fuel line **722** define an injector conduit **723** that supplies fuel from the fuel chamber **318** to the injector inlet **724**. It is contemplated that the injector conduit **723** could be defined by different elements, such as other and/or additional fuel lines.

To prevent or at least reduce short-circuiting of fuel between the fuel supply conduit **715** and the injector conduit **723**, the second height **720** and the first height **716** are selected such that a bottom of the injector conduit **723** and a bottom end of the fuel supply conduit **715** (in the fuel chamber **318**) are sufficiently far apart from each other (in the present embodiment, in a height direction). More particularly, the spacing is selected to prevent or at least reduce fuel entering the fuel chamber **318** from the fuel supply conduit **715** from short circuiting the fuel vapor separator **146** by flowing directly from the bottom end of the fuel supply conduit **715** to the bottom end of the injector conduit **723**.

In another aspect, some of the fuel supplied to the fuel injector **137** is recirculated back to the fuel tank **702**. To this end, the fuel injector **137** has an injector outlet **726** in fluid communication with the injector inlet **724** for recirculating some of the fuel supply received by the injector inlet **724**, for cooling the fuel injector **137**. A seventh fuel line **728** fluidly connects the injector outlet **726** to a top end of a Y-connector **738**. An eighth fuel line **741** is fluidly connected to a bottom end of the Y-connector **738** and extends downwards to the fluid connector **314**. A ninth fuel line **730** extends downward from the fluid connector **314** into the fuel chamber **318** of the fuel vapor separator **146** to a third height **732** measured from the bottom surface of the fuel chamber **318**.

A tenth fuel line **734** fluidly connects the Y-connector **738** to a check valve **736** and an eleventh fuel line **740** fluidly connects the check valve **736** to the fuel tank **702**. Fuel recirculated by the fuel injector **137** flows from the injector outlet **726** into the fuel tank **702** via the seventh fuel line **728**, the Y-connector **738**, the check valve **736** and the eleventh fuel line **740**. In other words, the seventh fuel line **728**, the Y-connector **738**, the check valve **736** and the eleventh fuel line **740** define a fuel return conduit **731** that returns some of the fuel supplied to the injector inlet **724** back to the fuel tank **702**. It is contemplated that the fuel return conduit **731** could be defined by different elements, such as other and/or additional fuel lines.

In the present embodiment, about 50% of the fuel supply to the injector inlet **724** is consumed by the internal combustion engine **134** when operating at maximum throttle (also referred to as "wide open throttle"), while the remaining 50% is recirculated back to the fuel tank **702**. At minimum throttle (also referred to as "idle"), about 1% of the fuel supply to the injector inlet **724** is consumed and 99% is recirculated back to the fuel tank **702**. It is contemplated the proportion between the rate of fuel consumption and the rate of fuel recirculation could be different depending on, for example, each particular embodiment of the internal combustion engine **134** and each particular embodiment of the fuel injector **137**.

To help reduce production of fuel vapor within the fuel vapor separator **146**, it is positioned relative to the engine assembly **102** such that when the marine outboard engine **100** is attached to a transom **148** (shown schematically in FIG. **1**) of a watercraft (not shown) in a body of water **150** and is in an in-use position, at least a part of the fuel vapor separator **146** is submerged in the body of water **150** (as shown in FIG. **1**).

The at least partial submergence of the fuel vapor separator **146** in the body of water **150** cools fuel in the fuel chamber **318** when the marine outboard engine **100** is in use. This helps reduce fuel vapor production in the fuel chamber **318**.

In another aspect, dining operation of the internal combustion engine **134**, fuel fills the fuel chamber **318** to the bottom end of the ninth fuel line **730** and creates a fuel column in the fuel chamber **318**, the fuel column having the third height **732**. To ensure that the fuel column that will cover the terminal opening (which is in the fourth fuel line **714** at the first height **716**) of the fuel supply conduit, the third height **732** is selected to be greater than the first height **716**. In some applications, this will reduce splashing of fuel entering the fuel chamber **318** from the fuel supply conduit. In turn, reduced splashing will also reduce fuel vapor production in at least some operating conditions.

Additionally, a conventionally known foam block **733** is disposed inside the fuel chamber **318**. The foam block **733** further helps reduce splashing of fuel inside the fuel chamber **318**. It is contemplated that in some embodiments, the foam block **733** could be larger or smaller than illustrated in FIG. **7**, or omitted entirely.

The fuel vapor produced by fuel in the fuel chamber **318** and pumped into the fuel chamber **318** from the fuel tank **702** accumulates in a column of gas that is trapped in the fuel chamber **318** above the column of fuel in the fuel chamber **318**. As more vapor accumulates, it pushes the fuel down, lowering the height of the fuel column and exposing the bottom end of the ninth fuel line **730**, which in turn allows vapor to escape through a vapor return conduit **739** formed by the ninth fuel line **730**, the fluid connector **310**, the eighth fuel line **741**, the Y-connector **738**, the check valve **736** and the eleventh fuel line **740**.

In the present embodiment, the outlet of the Y-connector **738** in fluid communication with the fuel chamber **318** is sized to have a smaller diameter than the inlet of the Y-connector **738**. This restriction, which could be positioned in the eighth fuel line **741**, the fluid connector **314** or the ninth fuel line **730**, is smaller than the diameter of the injector conduit **723** and therefore acts to maintain fluid pressure at the injector inlet **724** and prevents fuel from flowing from the fuel chamber **318** to the injector outlet **726**. It is contemplated that a restriction, such as the smaller diameter of the main outlet of the Y-connector **738**, would not be required where, for example, the diameter of the seventh fuel line **728** downstream of the Y-connector **738** would have a suitably-reduced diameter.

In the present embodiment, a part of the eleventh fuel line **740** extends through the fuel filter **706** into the fuel line **704**, and extends inside the fuel line **704** to the fuel tank **702**.

In the present embodiment, and as shown schematically in FIG. **7**, a part of the eleventh fuel line **740** extends inside the fuel line **704** through the whole length of the fuel line **704** and exits the fuel line **704** into the fuel tank **702**. In some embodiments, the eleventh fuel line **740** extends inside a part of the length of the fuel line **704**. In some embodiments, the eleventh fuel line **740** does not pass through the fuel filter **706**.

In many jurisdictions, lines used to transport fuel (whether in liquid or vapor form) within a vessel, such as between a fuel tank and an outboard engine, must meet strict regulations and are therefore very expensive. Therefore, in at least some jurisdictions, extension of the eleventh fuel line **740** inside the fuel line **704** allows the part of the eleventh fuel line **740** that is inside the fuel line **704** to be a relatively lower-grade fuel line (and therefore cheaper) than the fuel line **704**, while ensuring safety and maintaining compliance with applicable regulations. It is contemplated that all of the eleventh fuel line **740** could be positioned completely outside of the fuel line **704**, in which case, in at least some jurisdictions, all of the eleventh fuel line **740** would need to meet the same regulations (if any apply) as the fuel line **704**.

In the present embodiment, the check valve **736** is a conventionally known check valve that permits flow of fluid (which could be fuel and/or fuel vapor and/or air) from the fuel chamber **318** toward the fuel tank **702** when pressure of fluid in the tenth fuel line **734** (and therefore also in the vapor return conduit **739** fluidly upstream of the check valve **736**) is above a predetermined pressure threshold of the check valve **736**.

In the present embodiment, the check valve **736** is selected such that the predetermined pressure threshold is equal to the pressure of the fuel pump **710** (i.e. fifteen psi). Therefore, when pressure of fluid in the tenth fuel line **734** exceeds fifteen psi, the check valve **736** opens and fluid in the tenth fuel line **734** flows through the check valve **736** toward the fuel tank **702**. In other words, in the present embodiment, the tenth fuel line **734**, the check valve **736**, and the eleventh fuel line **740** define the vapor return conduit **739**. The vapor return conduit **739** fluidly connects the fuel chamber **318** to the fuel tank **702** when the check valve **736** is open.

By opening at the predetermined pressure threshold, the check valve **736** relieves pressure of fluid in the fuel chamber **318** to the fuel tank **702** via the vapor return conduit **739**. In some such cases, the fluid flowing through the check valve **736** is fuel vapor from the fuel chamber **318**. In some such cases, the fuel vapor in the fuel chamber **318** rises up through the ninth fuel line **730** and the eighth fuel line **741** to the Y-connector **738**. This fuel vapor then flows through the Y-connector **738**, the tenth fuel line **734**, the check valve **736** and the eleventh fuel line **740** to the fuel tank **702**. The fuel vapor can then be vented from the fuel tank **702** to ambient air via the fuel vapor pressure relief valve **703** of the fuel tank **702**.

In another aspect, when the pressure of the fluid in the vapor return conduit **739** upstream of the check valve **736** is below the predetermined pressure threshold of the check valve **736**, the check valve **736** is closed. When the check valve **736** is closed, the check valve **736** prevents fluid flow through the check valve **736**, and therefore prevents fluid flow through the vapor return conduit **739** in a fluid direction from the fuel chamber **318** toward the fuel tank **702**.

Also, irrespective of pressure of fluid in the tenth fuel line **734**, the check valve **736** prevents fluid flow through the check valve **736** (and therefore also through the vapor return conduit **739**) in a fluid direction from the fuel tank **702** toward the fuel chamber **318**. In one aspect, this helps ensure that fuel from the fuel tank **702** does not enter the fuel chamber **318** through the vapor return conduit **739**, in which case the fuel would bypass the fuel filter **706**.

The operation of the check valve **736** helps maintain pressure of fuel and fuel vapor in the fuel chamber **318** at the predetermined pressure threshold of the check valve **736**. In another aspect, the operation of the check valve **736** reduces fluid pressure variations in the fuel chamber **318** (and therefore also at the injector inlet **724** and the injector outlet **726**, which are fluidly connected to the fuel chamber **318**).

More specifically, during some operating conditions, variations in the fluid pressure output (that is, head) of the fuel pump **710** will occur, to a lesser or a greater degree depending on the particular embodiment of the fuel pump **710**. Some variations in the fluid pressure output of the fuel pump **710** will cause variations of the level of fuel in the fuel chamber **318** and corresponding compressions and expansions of the column of gas above the fuel in the fuel chamber **318**.

The corresponding compressions and expansions of the column of gas will dampen at least some variations in the fluid pressure output of the fuel pump **710**, and excessive expansions of the column of gas will be mitigated by being vented by the operation of the check valve **736** (described above). This creates a pressure buffering effect in the fuel chamber **318**. As a result, in at least some operating conditions, variations in the pressure of the fuel supply at the injector inlet **724** are smaller in magnitude than variations in the pressure output of the fuel pump **710**.

In some cases, this allows the fuel pump **710** to be selected as a fuel pump that has a relatively simpler construction and is relatively less precise in maintaining a given fluid pressure output, while maintaining the fuel supply to the injector inlet **724** within a range of pressures that is suitable for maintaining proper operation of the fuel injector **137**. In some cases, such fuel pumps are relatively cheaper than more complicated fuel pumps that are designed to provide a relatively more stable and more precise fluid supply pressure output. In some cases, simpler fuel pumps are more reliable than more complex fuel pumps.

Also, in the present embodiment, the fuel system of the marine outboard engine **100** operates on the single fuel pump **710**. In some cases, this reduces manufacturing costs of the marine outboard engine **100**. In some cases, this increases reliability of the marine outboard engine **100** (for example, due to the marine outboard engine **100** having a relatively smaller number of components).

Modifications and improvements to the above-described implementations of the present technology may become apparent to those skilled in the art. The foregoing description is intended to be exemplary rather than limiting.

The invention claimed is:

1. A fuel system for an internal combustion engine, the internal combustion engine being for use with a fuel tank and having a fuel injector, the fuel injector having an injector inlet for receiving a fuel supply and an injector outlet in fluid communication with the injector inlet for recirculating at least some of the fuel supply received by the injector inlet when the internal combustion engine operates, the fuel system comprising:

a fuel vapor separator defining a fuel chamber, the fuel chamber being a pressurizable fuel chamber, the fuel vapor separator including an elongate body defining the pressurizable fuel chamber therein, the fuel chamber being structured to have a column of gas in a top part of the fuel chamber when the fuel system operates;

a fuel supply conduit, a first end of the fuel supply conduit being fluidly connected to the fuel chamber, a second end of the fuel supply conduit being fluidly connectable to the fuel tank for supplying fuel from the fuel tank to the fuel chamber, a terminal opening at the first end of the fuel supply conduit being within the fuel chamber and being located at a first height measured from a bottom surface of the fuel chamber;

an injector conduit, a first end of the injector conduit being fluidly connected to the fuel vapor separator, a second end of the injector conduit being fluidly connectable to the injector inlet for supplying fuel from the fuel vapor separator to the injector inlet, a terminal opening at the first end of the injector conduit being within the fuel chamber and being located at a second height measured from the bottom surface of the fuel chamber, the second height being smaller than the first height;

a fuel return conduit, a first end of the fuel return conduit being fluidly connectable to the fuel tank, a second end of the fuel return conduit being fluidly connectable to the injector outlet for returning fuel from the injector outlet to the fuel tank; and

a vapor return conduit, a first end of the vapor return conduit being fluidly connected to the fuel vapor separator, a second end of the vapor return conduit being fluidly connectable to the fuel tank for supplying fuel vapor from the fuel vapor separator to the fuel tank, a terminal opening at the first end of the vapor return conduit being within the fuel chamber and being located at a third height measured from the bottom surface of the fuel chamber, the third height being greater than the first height.

2. The fuel system of claim **1**, further comprising a pulse pump fluidly connected to the fuel supply conduit to be operable to supply fuel from the fuel tank to the fuel chamber via the fuel supply conduit when the second end of the fuel supply conduit is fluidly connected to the fuel tank.

3. The fuel system of claim **1**, wherein:

the fuel system includes the fuel tank,

the second end of the fuel supply conduit is fluidly connected to the fuel tank, and

the fuel tank has a pressure relief valve operable to release fuel vapor pressure in the fuel tank to ambient air when the fuel vapor pressure reaches a first predetermined pressure threshold.

4. The fuel system of claim **1**, wherein:

the fuel system includes a check valve positioned in the vapor return conduit, and

the check valve:

prevents fluid flow through the check valve in a fluid direction from the fuel tank toward the fuel vapor separator,

prevents fluid flow through the check valve in a fluid direction from the fuel vapor separator toward the fuel tank when fluid pressure in the vapor return conduit fluidly upstream of the check valve is below a second predetermined pressure threshold, and permits fluid flow through the check valve in the fluid direction from the fuel vapor separator toward the fuel tank when fluid pressure in the vapor return conduit fluidly upstream of the check valve is above the second predetermined pressure threshold.

5. The fuel system of claim **4**, wherein the vapor return conduit includes a vapor return line fluidly upstream of the check valve, the terminal opening at the first end of the vapor return conduit being in one end of the vapor return line.

6. The fuel system of claim **1**, wherein the vapor return conduit and the fuel return conduit fluidly overlap at least in part.

7. The fuel system of claim **6**, wherein the fuel return conduit includes a fuel return line and the vapor return conduit includes a vapor return line physically connected to the fuel return line.

8. The fuel system of claim **1**, wherein the vapor return conduit includes a vapor return line, the fuel supply conduit includes a fuel line, and the vapor return line is located within the fuel line.

9. The fuel system of claim **1**, wherein:

the fuel system includes a fuel filter fluidly positioned in the fuel supply conduit,

the vapor return conduit includes a vapor return line,

the fuel supply conduit includes a fuel line, and

the vapor return line is within the fuel line at least between the fuel filter and the fuel tank.

10. A marine outboard engine, comprising:

an internal combustion engine having a crankshaft, a fuel injector, the fuel injector having an injector inlet for receiving a fuel supply and an injector outlet in fluid communication with the injector inlet for recirculating at least some of the fuel supply received by the injector inlet when the internal combustion engine operates;

a driveshaft having a first end connected to the crankshaft, and a second end opposite the first end;

a transmission connected to the second end of the driveshaft to be driven by the driveshaft;

an output shaft having a first end connected to the transmission to be selectively driven by the transmission, and a second end opposite the first end;

a rotor connected to the second end of the output shaft to driven by the output shaft for propelling the marine outboard engine;

a fuel vapor separator defining a fuel chamber, the fuel chamber being a pressurizable fuel chamber, the fuel vapor separator including an elongate body defining the pressurizable fuel chamber therein, the fuel chamber being structured to have a column of gas in a top part of the fuel chamber when the internal combustion engine operates;

a fuel supply conduit, a first end of the fuel supply conduit being fluidly connected to the fuel chamber, a second end of the fuel supply conduit being fluidly connectable to the fuel tank for supplying fuel from the fuel tank to the fuel chamber, a terminal opening at the first end of the fuel supply conduit being within the fuel chamber and being located at a first height measured from a bottom surface of the fuel chamber;

an injector conduit, a first end of the injector conduit being fluidly connected to the fuel vapor separator, a second end of the injector conduit being fluidly connected to the injector inlet for supplying fuel from the fuel vapor separator to the injector inlet, a terminal opening at the first end of the injector conduit being within the fuel chamber and being located at a second height measured from the bottom surface of the fuel chamber, the second height being smaller than the first height;

a fuel return conduit, a first end of the fuel return conduit being fluidly connectable to a fuel tank, a second end of the fuel return conduit being fluidly connected to the injector outlet for returning fuel from the injector outlet to the fuel tank; and

a vapor return conduit, a first end of the vapor return conduit being fluidly connected to the fuel vapor separator, a second end of the vapor return conduit being fluidly connectable to the fuel tank for supplying fuel vapor from the fuel vapor separator to the fuel tank, a terminal opening at the first end of the vapor return conduit being within the fuel chamber and being located at a third height measured from the bottom surface of the fuel chamber, the third height being greater than the first height.

11. The marine outboard engine of claim **10**, wherein:

the marine outboard engine includes a check valve positioned in the vapor return conduit, and the check valve:

prevents fluid flow through the check valve in a fluid direction from the fuel tank toward the fuel vapor separator,

prevents fluid flow through the check valve in a fluid direction from the fuel vapor separator toward the fuel tank when fluid pressure in the vapor return conduit fluidly upstream of the check valve is below a second predetermined pressure threshold, and

permits fluid flow through the check valve in the fluid direction from the fuel vapor separator toward the fuel tank when fluid pressure in the vapor return conduit fluidly upstream of the check valve is above the second predetermined pressure threshold.

12. The marine outboard engine of claim **10**, wherein the vapor return conduit and the fuel return conduit fluidly overlap at least in part.

13. The marine outboard engine of claim **10**, wherein the vapor return conduit includes a vapor return line, the fuel supply conduit includes a fuel line, and the vapor return line is located within the fuel line.

14. The marine outboard engine of claim **10**, wherein the elongate body extends at least in part parallel to the driveshaft.

15. The marine outboard engine of claim **14**, wherein the fuel vapor separator is positioned relative to the internal combustion engine such that when the marine outboard engine is attached to a transom of a watercraft in a body of water and is in an in-use position, at least a part of the fuel vapor separator is submerged in the body of water.

16. The marine outboard engine of claim **14**, wherein the elongate body is located below the crankshaft and above the output shaft.

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